Transportation Synthesis Report

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Alternative Dowel Bar Materials for Concrete Pavement Joints

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Transportation Synthesis Reports (TSRs) are brief summaries of currently available information on topics of interest to WisDOT technical staff in highway development, construction and operations. Online and print sources include NCHRP and other TRB programs, AASHTO, the research and practices of other state DOTs, and related academic and industry research.

REQUEST FOR REPORT

Some studies demonstrate the corrosion resistance of epoxy-coated dowel bars for concrete joints. A 1996 WisDOT study on "Random Skewed Joints With and Without Dowels," for instance, claims no corrosion after five years at installed sites. See http://www.dot.wisconsin.gov/library/research/docs/finalreports/tau-finalreports/skewedjoints.pdf. However, corrosion resistance benefits from epoxy coatings can be offset when the concrete surrounding the dowel scrapes this shell during installation or pavement load transfer moments, rendering dowels vulnerable to corrosion and shortening their functional lives. To address this issue, the RD&T Program was asked to review and report on studies of alternative materials for dowel bars, such as fiber-reinforced polymer dowels, stainless-steel clad dowels, and solid stainless steel dowels.

SUMMARY

A 2002 review of dowel bar research provides an excellent summary of current knowledge. See Iowa's "Assessment of Dowel Bar Research" below. Several long-term research efforts are in progress but not yet complete, including promising work in Iowa and an oft-mentioned project by the Civil Engineering Research Foundation's Highway Innovative Technology Evaluation Center (HITEC).

Iowa appears to lead other states in research of alternative-material dowels, and has focused particular attention on FRP or glass fiber-reinforced polymer (GFRP) dowels. Generally, research shows that FRPs transfer load less efficiently than stainless steel, because they lack the stiffness of the latter material. Yet carefully designed and installed FRPs typically outperform epoxy-coated bars, and the cost of these dowels effectively bridges the expense gap between epoxy-coated bars and stainless-steel bars. Gaps in research remain, particularly in the long-term performance of these alternative products, but research in progress may provide the answers.

IOWA

Iowa's special material emphasis has been on glass fiber-reinforced polymer dowels, with many studies from Iowa State University's Max Porter and his cadre of graduate students.

"Assessment of Dowel Bar Research." http://www.ctre.iastate.edu/reports/dowelbarsynthesis.pdf. Published Aug. 2002, this invaluable study identifies research and gaps. It summarizes significant research on dowel bars and alternatives from 1989 to present, current research of interest, and identifies research topics still in need of exploration or refinement. The report presents the objectives, a description, and the conclusions of each study summarized. It also includes a description of current theoretical work on dowel bars, and offers a solid bibliography of dowel bar research.

This study focuses primarily on the most popular alternative to epoxy-coated steel – glass fiber-reinforced polymer dowels – and offers attention to stainless steel designs (see pp. 43-44, for example), as well. Findings of note include:

- Extensive loading and environmental pressure significantly impair the maximum strain capacity and tensile strength of GFRP, which is already less than steel dowels (20).
- Many metallic and non-metallic coatings have been tried on steel dowels with mixed results, and epoxy has emerged favorably. GFRP appears to be the most popular alternative to traditional steel, using E-glass cores and vinyl-ester or epoxy resin shells (25).
- Stainless steel dowels "may be reliable and cost effective," and FRP dowels are successful "when correct diameters and spacings are specified" (25).
- Certain GFRP dowels outperform epoxy-coated steel dowels (29).
- Steel transfers more load than fiberglass due to its stiffness, and curing and warping of concrete can impact dowel bond, but the dowels can also reduce the impact of curing and warping on concrete (36).
- GFRP dowels have been researched more than stainless-steel, which is now drawing more attention. Studies of the latter fall almost entirely into the Current Research section, rather than Previous Research (see pp. 41ff).
- Significant gaps exist in research of GFRP and stainless steel dowels. Those detailed include studies of the effect of moisture and aging on FRP dowels, of the efficacy of elliptical and other non-circular dowel shapes, FRP design criteria, standardized procedures for testing and evaluating bars of various materials, long-term fatigue performance of GFRP (59ff).

"Investigation of Glass Fiber Composite Dowel Bars for Highway Pavement Slabs," ML Porter, RJ Guinn, Jr, AL Lundy, DD Davis, JG Rohner. 182 pages, report no. TR-408, Iowa State University and Iowa DOT; June 2001. For summary, see pp. 32-34 of "Assessment," above. http://199.79.179.82/sundev/detail.cfm?ANNUMBER=00928020&STARTROW=31&CFID=198178&CFTOKEN=90243053 (abstract). Compares epoxy-coated to stainless steel and glass fiber-reinforced polymer dowels, focuses computer simulation testing models on GFRP. Significant findings include:

- 1.5-inch GFRP spaced at 12 inches on center were inadequate in transferring load, but at 6 inches were effective.
- Steel dowel design guidelines cannot be applied to GFRP dowels.

CERF'S MULTI-STATE STUDY

Industry groups have been calling in recent years for more research on dowel bar failure and feasibility of stainless-clad or alternatives. In 1996, the Civil Engineering Research Foundation's Highway Innovative Technology Evaluation Center (HITEC) pushed for a multi-state, five-year-or-more study of alternative material dowels. The project is a non-proprietary evaluation program sponsored by the Composites Institute and the Specialty Steel Industry of North America. FHWA consults with HITEC and CERF on this project, and Wisconsin is one of several state DOTs represented on the study panel.

Civil Engineering Research Foundation. "Alternative Material Dowel Bars for Rigid Pavement Joints," http://www.cerf.org/hitec/eval/ongoing/dowel.htm. Multiple references to this study can be found in government sources and industry publications, suggesting industry buzz for this project.

- Began in 1996 with industry innovations, involves Illinois, Iowa, Minnesota, Ohio, Wisconsin in field placements of FRP and stainless-steel dowels. Promises results of study in 2003.
- Evaluation Plan http://www.cerf.org/pdfs/hitec/Dowels%20Final%20Evaluation%20Plan.pdf describes phases including field installation inspection, removal and testing; lab testing, new installation, and monitoring for up to five years. Domestically produced dowels are used. Evaluations include literature review, and tests and monitoring focus on joint condition, dowel position and load transfer. Involved parties will receive quarterly reports, and HITEC will issue a final report after a five-year monitoring period.
- "Noncorrosive Dowel Bars to be Evaluated," *Civil Engineering*, v. 69, no. 9, Sept. 1999, p. 26. Describes this five-year study of FRP and stainless bars to determine corrosion resistance. See abstract of article at http://199.79.179.82/sundev/detail.cfm?ANNUMBER=00778165&STARTROW=31&CFID=198178&CFTOKEN=90243053.
- Construction Industry Institute. "Alternative Material Dowel Bars for Rigid Pavement Joints," http://www.new-technologies.org/ECT/Civil/dowelbars.htm.

FHWA'S HIGH PERFORMANCE CONCRETE PROGRAM

In a recent article about HPCP efforts, a section on dowel bars draws from the experience of the states involved in the CERF study in a one-year assessment from that project.

"Fine Tuning Innovative Technologies," Mark Swanlund, *Public Roads*, July/August 2002. http://www.tfhrc.gov/pubrds/02jul/03.htm. Various dowel materials. These include fiber-reinforced composites (FRC), grout-filled FRC, stainless steel, grout-filled stainless steel, and stainless steel-clad dowels. Details include:

- FRC dowels transfer less load than steel.
- Stainless steel is the most expensive option. Stainless-clad dowels cost $14, and all-stainless $20. FRCs, which seem to be corrosion resistant, cost $7 to $10; epoxy-coated dowels cost $3.

Periodic Updates. Periodic studies will emerge from the CERF multi-state project, and will be submitted to HPCP. States participating will be Wisconsin (report due Spring 2004), Illinois (2002), Ohio (2002), Kansas (2003) and Iowa (2003, 2005). See project description, http://www.fhwa.dot.gov/pavement/cptp23.htm.

TRB 2003 ANNUAL MEETING PAPERS

Numerous papers at the January 2003 TRB Annual Meeting mention dowel bars of various materials – usually GFRP, sometimes stainless steel – but only one paper compares the performance and costs of the options.

"Minnesota's High Performance Concrete Pavements: Evolution of the Practice," presented by Curt Turgeon, Research Operations Engineer, Mn/DOT. This project employed "corrosive resistant dowel bars" instead of the traditional Mn/DOT dowel of epoxy-coated steel. The relevant material is discussed on p. 5 of the paper under the heading "Load Transfer." Specific details include:

- Of the 41,625 dowels used, 36,650 were stainless-steel clad, produced by a manufacturer in the United Kingdom. FRP was considered, but dismissed for lack of data on long-term performance (6).
- p.7: Supply at the time of this study – in 2002 – was limited, but Mn/DOT offered prices that were in effect: 3.8 cm stainless-clad (preferred size) were $11.60 each, 4.4 cm stainless-clad $14.30; all-stainless dowels were $19.70 (7).

RESEARCH IN PROGRESS

In a pair of completed reports, Arkansas found in 1994 that with fiber-reinforced polymer dowels, 1.5-inch bars are superior to 1.25-inch steel in load stress and transfer characteristics (see abstract, http://rip.trb.org/browse/dproject.asp?n=6803); Kansas confirmed in a three-year study completed in 2002 that stainless-steel bars resist corrosion better than conventional (see abstract, http://rip.trb.org/browse/dproject.asp?n=7420). Several other TRB projects will, when completed, have relevance for long-term performance of alternative material dowels.

Iowa. "Field Evaluation of Alternative Portland Cement Concrete Pavement Reinforcement Materials," conducted in Warren County. http://www.dot.state.ia.us/materials/research/current_projects/h1000_series_listing.html#HR-1069 (abstract). This study, still in process, evaluates comparative field performance of two brands of fiber composite dowels, stainless steel dowels, and epoxy-coated steel dowels.

Iowa. "Glass Fiber Composite Dowel Bar for Highway Pavement," http://rip.trb.org/browse/dproject.asp?n=2945 (abstract). Investigates long-term performance and fatigue behavior of glass fiber composite dowels, as alternative to epoxy-coated steel dowels. Started 6/2/1997, TRB Accession No. 759936.

Utah. "Stainless Clad Reinforcing Steel Evaluation," http://rip.trb.org/browse/dproject.asp?n=7957 (abstract). Since January, 2001, Utah has been evaluating the potential efficiencies and long-term savings of using 316L stainless-clad rebar instead of epoxy-coated rebar. This may be useful as a general study of materials in question.